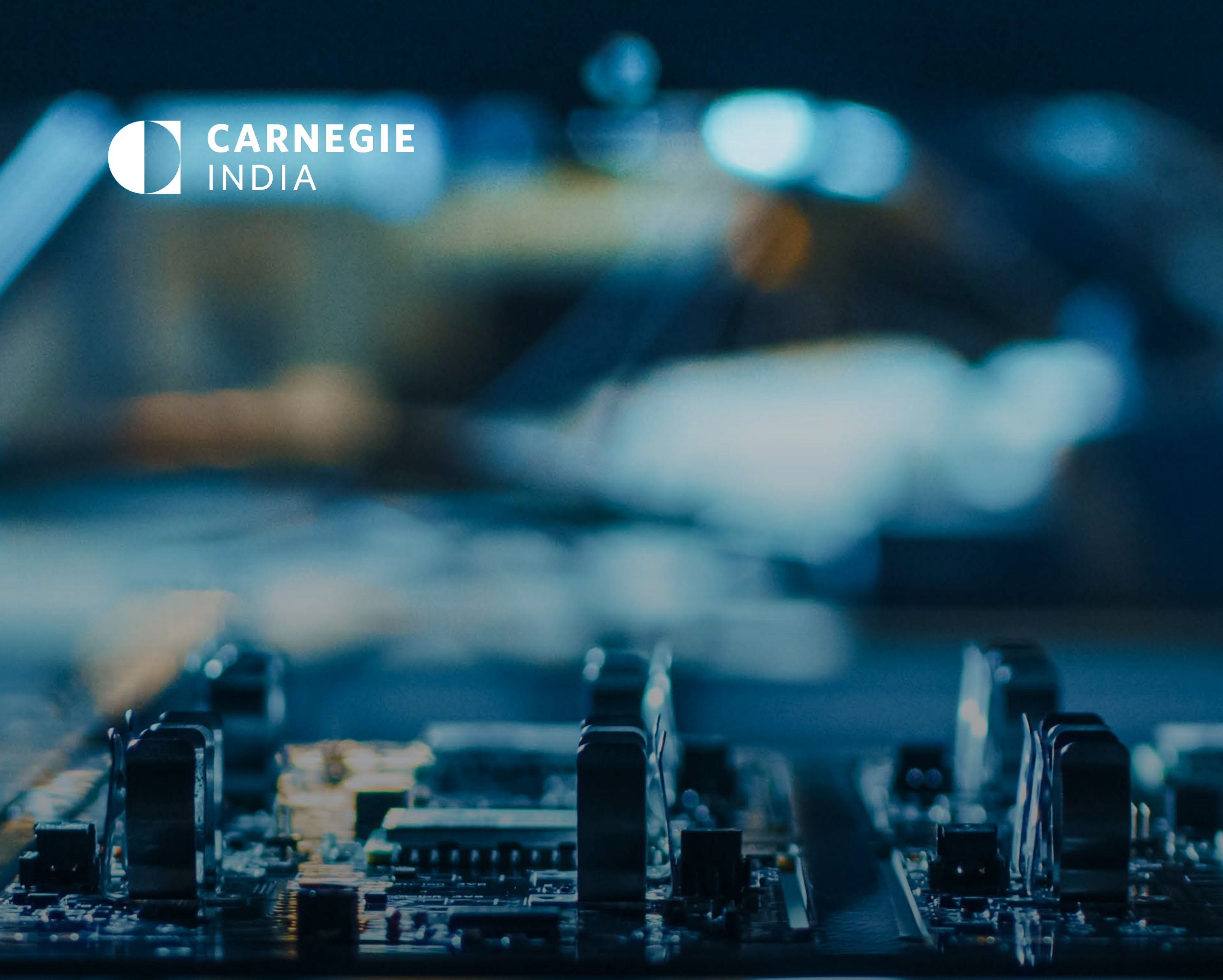

How Washington and New Delhi Can Further Tech Ties

Rudra Chaudhuri, editor

Priyadarshini D. | *Konark Bhandari* | *Arjun Kang Joseph* | *Shatakratu Sahu*

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INTRODUCTION

RUDRA CHAUDHURI

On May 24, 2022, Indian Prime Minister Narendra Modi and U.S. President Joe Biden launched the bilateral Initiative on Critical and Emerging Technologies (iCET) in Tokyo. The initiative is "spearheaded by the National Security Councils of the two countries," and its primary objective is to "expand partnership in critical and emerging technologies." Scientific and technological cooperation between India and the United States goes back to the Green Revolution. Since then, a range of government-led initiatives have set out joint funds for projects, created dialogue platforms to focus on easing export controls, and set up forums and projects to focus on clean energy, among other creative initiatives.

Yet, what sets the iCET apart from any other initiative thus far is that it is co-led by the National Security Council Secretariat (NSCS) in India and the National Security Council (NSC) in the United States. From AI to space to quantum computing to semiconductors, the NSCS and the NSC are tasked to "forge closer linkages between government, academia and industry of the two countries." As those who have long worked in government and industry in both countries put it, the NSCS and the NSC have the potential to coordinate a set of imperatives that is focused, outcome-oriented, and implementation-minded.

These administrative bodies have every chance to coordinate policies more clearly across line ministries in both countries, seek out prospects, clearly outline pain points, and lead a set of conversations more holistically than is structurally possible through any one ministry, department, or government agency. In short, the iCET is a clever, agile, and far-sighted initiative. To an extent, it has the potential to cut through red tape, avoid bureaucratic minefields, and enable the growth of an interoperable critical technologies ecosystem within and between India and the United States. Setting an agenda for the iCET will require making tough calls across a laundry list of potential areas of cooperation.

To this end, the Technology and Society Program at Carnegie India offers a set of recommendations in four specific areas of critical technologies: building a stronger science and technology cooperation ecosystem, collaborating in quantum computing, civilian space cooperation, and building a framework for cooperation on specific aspects of the semiconductor supply chain. The team has spent the months since the announcement of the iCET in May 2022 speaking with stakeholders in government, industry, and academia in both countries.

This compendium offers initial thinking on what might be considered within the iCET framework. In each of the sections, the authors provide specific recommendations that can be achieved within the next six months, the following year, and beyond. They have balanced the need to focus on cutting-edge ways in which cooperation could be quickly but substantially advanced without losing sight of the longer-term and traditional areas of disagreements, such as the urgent need to focus on export control regimes that are essential to "forge closer linkages."

Importantly, the aim is to provide an independent and research-driven bridge for dialogue between government, academia, and industry in the two countries, the parties that have the most to gain from deeper, immersive levels of cooperation in and across emerging and critical technologies.

CHAPTER 1

BOOSTING INDO-U.S. SCIENCE AND TECHNOLOGY COLLABORATION THROUGH ICET

PRIYADARSHINI D.

Indo-U.S. scientific and technological cooperation has a long history. American funds, philanthropic organizations, and scientists all played a role in helping usher in the Green Revolution in India in the 1960s. The following decades, especially the last two, significantly expanded the bilateral cooperation in science and technology (S&T). Both countries established the jointly funded Indo-U.S. Science and Technology Forum (IUSSTF) in 2000. The IUSSTF facilitates scientific research and development through joint workshops, student and faculty exchanges, virtual research centers, and technology transfer programs. It also administers the U.S.-India Science and Technology Endowment Fund (USISTEF), which was established in 2009 and has an annual budget of up to $3 million. It is earmarked to promote commercialization of jointly developed innovative technologies. Both countries also launched the Partnership to Advance Clean Energy (PACE) the same year to support research and commercialization of clean energy technologies.

Other examples include the India-U.S. High Technology Cooperation Group established in 2002. To an extent, the group has eased exports of high technology, including dual-use items, to India. A biennial process of Joint Committee meetings agreed to in 2005 provides strategic guidance to scientific agencies in both countries on current and future S&T initiatives. The Indo-U.S. civil nuclear deal of 2005 is perhaps the most significant, coming on the heels of a dip in bilateral relations between the two following India's nuclear tests. The more recent IUSSTF's U.S.-India Artificial Intelligence Initiative provides a platform for strategic cooperation in AI.

The S&T cooperation between both countries has been wide ranging, from collaboration in fundamental scientific research to applications in clean energy, health, agriculture, environment, and climate change. Formal mechanisms as above have coexisted alongside informal, people-to-people linkages in academia. The recently announced iCET program offers a new avenue to take this bilateral engagement further.

Based on preliminary research and stakeholder consultations, the iCET could strengthen Indo-U.S. cooperation in critical and emerging technologies (CETs) by providing a platform for fixing information asymmetries; developing a future-ready technical workforce; establishing robust stakeholder linkages via translational institutions or centers of excellence; facilitating risk capital for research, development, and deployment of CETs; and creating appropriate institutional frameworks and structures to support iCET goals in the short, medium, and long term.

ICET INNOVATION FELLOWSHIPS, HACKATHONS, AND DIALOGUES

The iCET is expected to bring the government, academia, and industry of both countries together on critical and emerging technologies and deliver "outcome-oriented cooperation." Immediate action points could include the use of tools and strategies like jointly organized fellowship programs, a series of hackathons or competitions, and dialogues.

The iCET fellowship program could help identify and train talent at top institutions and create bilateral networks of specialists and experts. It could be co-funded by both governments and the private sector or fully funded by the private sector. The Quad fellowship program offers an example. It is administered by Schmidt Futures, a private philanthropic organization. The iCET fellowships could similarly look to large university endowments in the United States, philanthropic organizations in both countries, and multinational companies such as IBM or Intel as sponsors. Such fellowships could be offered in quantum technologies or biotechnology, to begin with.

A series of iCET innovation hackathons can be jointly held to forge iCET networks involving industry, academia, government, and civil society. For example, the G20 TechSprint is organized by the G20 president every year to encourage solutions to technological issues. Typically, it has been co-sponsored by central banks, international bodies like the Bank for International Settlements, as well as the private sector, including big tech companies like Facebook. Another example is the series of Challenge Programmes proposed by the recently set up Defence Innovation Accelerator for the North Atlantic under NATO. Each program is expected to elicit and nurture the best technological solutions to urgent security problems. The iCET innovation hackathons could similarly be organized in collaboration with leading universities and technology companies from both countries. In addition to signaling action, such platforms could mobilize ideas, identify innovative solutions to crucial problems, as well as crowdsource and cultivate private sector and start-up capabilities.

Both countries could also convene a jointly held series of iCET Innovation Dialogues in 2022–2023. As an example, since 2018, the United States Bureau of Economic and Business Affairs has been holding innovation roundtables through which it has engaged various industry stakeholders in areas such as the Internet of Things, blockchain, AI, and cloud computing, among others. Other examples include bilateral dialogues like the U.S.-India Strategic Dialogue. Accordingly, the iCET innovation dialogues could be a series of key sector- or technology-specific dialogues with multistakeholder participation.

Such dialogues could help map the complementarities between India and the United States in each area, policy-related challenges, as well as opportunities for joint research and development, since each of these could be sector or technology specific. The complementarities would also allow the government and the private sector to indicate their requirements (for example, with regard to skilling and workforce needs in transformational technologies like quantum computing). Industry participation should be diverse to include smaller businesses, too, from both countries. This could help them overcome information gaps related to policies, procedures, opportunities, and funds.

The inaugural dialogue could be organized as a track 1.5 dialogue convened by the two countries' National Security Councils or co-convened with think tanks and industry associations. This could be in a specific sector of mutual strategic interest and importance such as next generation critical infrastructure like 6G or emerging risks from biotechnological innovations. It could also be in quantum technologies, which both countries have accorded policy priority and significant funding. One of the outcomes could be the announcement of joint research projects as well as the iCET fellowship program mentioned above. These ties could go a long way in fashioning a firm and longer-term agenda for the iCET.

ICET TRANSLATIONAL INSTITUTION(S) AND COMMON FUTURES FUND

The next step, in the medium term, would be to ground the initial exercises in sustainable formats. There are several models that may be considered either individually or collectively. One or more technology-specific centers of excellence and translational institutions could be established to accelerate bilateral cooperation in CETs. Such institutions can support and fund cutting-edge research, translate and scale innovations from lab to market, and train the necessary technical workforce. They can be housed and co-funded by a network of Indian and U.S academic institutions and the private sector. For example, a consortium consisting of premier academic institutions, like the MIT Center for Theoretical Physics and the Indian Institute of Science, along with philanthropic organizations and private companies like Microsoft, IBM, and Google, could set up a center of excellence for quantum technologies. Such centers could also develop and offer dual degree or twinning programs and create relevant curricula for a seamless training and flow of talent.

Another model is UK Research and Innovation (UKRI), a dedicated public body in the United Kingdom with branches around the world, including in India (called UKRI India). It has a dedicated fund for international collaborations. These funds have been allocated through individual cells on a project-to-project basis, rather than through an overarching fund. UKRI has jointly (with the Indian government and other third parties) invested over 300 million pounds (around $345 million) and is understood to be a reasonably successful model. The National Science Foundation—currently identified as one of the implementing mechanisms for iCET on the American side—could also consider establishing a dedicated branch in India. Existing mechanisms like the jointly funded IUSSTF and the USISTEF can also be leveraged by the iCET. In each case, joint bidding of projects by academia and industry (including start-ups) from both countries, in partnership or consortium, must be encouraged to incentivize and increase collaborative projects.

A more ambitious model could be to set up a dedicated fund. One example is the $7.9 million PACEsetter Fund, jointly funded by both governments for early stage innovations in off-grid clean energy solutions. India and the United States also launched a public-private partnership to mobilize $41 million to support clean energy entrepreneurs. Private partners include university-led start-up incubators, U.S. aid agencies, Indian industry associations, and global nonprofit research organizations. Another example is the recently announced, 1-billion-euro NATO Innovation Fund to fund the development of dual-use emerging and disruptive technologies. Interestingly, it has been set up as a venture capital (VC) fund with participation from twenty-two allies and is the world's first multisovereign VC fund. Currently, no dedicated funds have been announced in relation to iCET. The existing partnership between the U.S. National Science Foundation and the Indian Department of Science and Technology has been identified as an implementing mechanism for iCET at the moment. The current expectation, therefore, appears to be to utilize existing bilateral funding and mechanisms. However, access to sufficient risk capital is a key constraint in accelerating developments in critical and emerging technologies. Therefore, a dedicated fund could be considered to finance CETs projects under the iCET, drawing from the public as well as the private sector resources, including venture funds focused on deep tech.

INSTITUTIONAL FRAMEWORK

In the short term, the iCET could leverage existing pools of expertise and resources available within the government, industry, and academia, as illustrated above. A key question for the iCET going forward will be the nature of institutional capacity it will need to create, both within and without, for sustainable bilateral engagement.

The research and policymaking on areas of CETs is fragmented among multiple bodies on both sides. In the longer term, creating a formal joint high-level committee, led by the National Security Councils from both sides, could help in coordinating action among domestic agencies. The committee could act as a nodal agency for both countries on CETs. It could be tasked with developing broader bilateral policies that could then be supplemented with national strategies.

Further, the committee could be assisted by multistakeholder working groups or task forces in specific areas or technologies (for example, supercomputing, quantum, or biotechnology). The latter could be co-anchored in academic institutions or think tanks. The committee would set the broader agenda, and the working groups or task forces would undertake deliberations. They would seek to deliver specific outcomes (in the form of recommendations or action plans) that in turn would provide a feedback loop to the committee. Regular meetings of the committee could review progress.

Examples of similar mechanisms include the India-U.S. High Technology Cooperation Group and the U.S.-India Energy Dialogue, both of which are also augmented by working groups. Working groups or task forces could, as in the case of the Clean Energy Finance Task Force under PACE, focus on specific areas such as identifying innovative financing solutions for early- and late-stage innovations or recommending procedures and documentation for accelerating bilateral cooperation. Another example is the arrangement between Japan and the United States involving the Joint High-Level Committee formed under an agreement in 1988. Since then, the committee has met fourteen times and appears to have had some success in aligning objectives and strategies in S&T. While the Japanese committee lacked a "strategic" or defense angle, due to Japan's domestic political compulsions, the iCET could bring in the security element and aid a more comprehensive framework for emerging technologies.

A key aspect of this framework will also be to include resolution mechanisms at the appropriate level to address any potential differences or divergences. For example, while both countries identify cooperation in AI as a key agenda under the iCET, policies around access and storage of data will require sustained engagement to move forward.

CONCLUSION

The initiative is both promising and timely, given how rapidly CETs are transforming societies and the economic and security landscape around the world. Washington expects to support at least twenty-five joint research projects in 2022 under the iCET. It has identified areas like AI and data science, and related applications in sectors like agriculture, health, and climate, for this purpose. Meanwhile, India expects to cooperate more broadly on AI, quantum computing, 5G/6G, biotech, space, and semiconductors under the iCET. The enumeration on both sides is presently nonexhaustive. The United States also annually updates a list of what it considers CETs. The list, prepared by the National Science and Technology Council in consultation with the NSC and other federal agencies, contains nineteen areas including AI, biotechnology, advanced computing, and quantum information technologies. India, although it has launched initiatives and acknowledged the importance of emerging technologies, does not have a similar, institutionally prepared list as yet. A common and concrete expression at the outset on the technologies and joint priorities for both National Security Councils may therefore be a useful way forward, to begin with.

CHAPTER 2

INDIA-U.S. SPACE COOPERATION

KONARK BHANDARI

In June 2022, the Indian prime minister inaugurated the headquarters of the Indian National Space Promotion and Authorization Centre (IN-SPACe). The inauguration was the latest event in the Indian space calendar, which has been abuzz with activity. The inauguration was quickly followed by the launch of payloads of two Indian private space start-ups, onboard the Polar Satellite Launch Vehicle managed by the Indian Space and Research Organization. Soon thereafter, Digantara, an Indian space startup, opened India's first-ever space situational awareness observatory to monitor satellites, space debris, and general space activity. The recent setting up of IN-SPACe is part of the larger liberalization of the space sector in India, which has largely been led by India's national space agency, the Indian Space Research Organization (ISRO), since the 1960s. The new reforms promise to put private space companies on par with space agencies like ISRO and its sister agencies.

Thus far, the Indian space program has earned a place of pride among Indians for largely punching above its weight—from launching satellites to building rockets using indigenous technology and launching successful missions to the moon and Mars.

As the prospect of humans becoming a spacefaring civilization takes root, these extraterrestrial missions will become more commonplace. In turn, they will require private sector supplies of communication equipment, transportation systems, robotics, and other technologies as ISRO focuses more on R&D in the time to come. However, given the nascent stage of the private sector in India, the germination of such technologies may take time. Given the considerable prowess of American enterprises when it comes to cutting-edge space technology, U.S.-India tech cooperation in the space sector may become critical since this could fill a void when it comes to the transfer of technology and collaboration on space missions. Going at it alone in space exploration missions may be a long-term strategy for India, but there is no denying that the industrial base that will propel such missions could benefit considerably from U.S. cooperation. Similarly, U.S. firms could benefit from access to the Indian procurement market as well as through co-development of cutting-edge technologies with their Indian counterparts.

Some of the key recommendations as to how this can be achieved are as follows.

Jointly held competitions. In the short run, India could conduct joint competitions with the United States in hackathons that bring together space entrepreneurs from both countries. The United States already does this with other partners. For instance, the UK Space Design Competition is a U.S.-UK science, business, and engineering challenge that requires participants in the UK to come up with a detailed design for a settlement in outer space. The participants are judged by experts from the UK Space Agency, and the winning teams eventually go to the NASA Kennedy Space Center for another round of demonstrations. The ISRO-NASA Space Apps 2022 challenge is also a good example of this as it is a competition wherein teams are required to use earth observation data to develop solutions for futuristic global problems.

Clarity on participation by private players in India's space ecosystem. The Indian government has introduced a series of draft policies aimed at liberalizing various aspects of India's space ecosystem. These include policies on space transportation, satellite navigation, and satellite communication. However, these policies are still to be finalized and are sector specific. The government is aware of this issue and is in the process of releasing a space bill together with a national space policy soon. The space bill, in particular, should define the scope of permissible foreign direct investment in the sector. This would provide much-needed clarity to firms in the United States regarding the degree to which they can participate in the Indian space sector.

Fine-tuning the U.S.-India Joint Working Group on Civil Space Cooperation (JWG). The U.S.-India JWG, established in March 2005, seeks to exchange views and expand cooperation in the realm of civil space activities. However, it appears that commercial cooperation in space has not been an area of focus between the two countries, as per the JWG. Compare this with the India-France Joint Vision for Space Cooperation signed in March 2018. This agreement aims to establish a bilateral space dialogue that would involve experts from not just the defense and space agencies but also the space ecosystem to discuss economic challenges in outer space. Indeed, out of the six countries that are helping India with its Gaganyaan mission, France figures prominently. The United States and India ought to consider deepening the nature of their partnership through more commercial exchanges in this area as well. Accordingly, adding a commercial element (through participation of their private sector companies) to the JWG should be considered.

Promoting trade in high-tech items. The International Traffic in Arms Regulations and Export Administration Regulations, regulated by the United States State Department and Department of Commerce respectively, are relevant for Indian and American companies when it comes to working on and co-developing technologies. However, even though India enjoys a Strategic Trade Authorization-1 exemption issued by the U.S. Department of Commerce in 2018, the figures for 2021 show that U.S. exports to India shipped under a U.S. Bureau of Industry and Security license exception authorization only totaled $325.8 million, a decrease from $340.2 million in 2020. Also, there were eleven license applications denied in 2021, amounting to $13.7 million. Therefore, the overall story here appears to be one of a low degree of trade taking place. Even so, stakeholder consultations revealed that while denials are few, the paperwork required to comply with U.S. export control laws is burdensome. Washington may consider revising this framework in light of the fact that other nations that are not encumbered by the regulations could gain market share at the expense of American firms.

In conclusion, the United States has been an enduring partner of India when it comes to space cooperation over the last few decades. Even Chandrayaan-1 carried a U.S.-developed moon mineralogy mapper and a miniature synthetic aperture radar. The positives of this mission serve to highlight the fact that larger benefits could accrue to both sides, provided they step up their high-tech cooperation in the space sector. This would require increasing interface between private space enterprises of both countries and Washington and New Delhi creating the necessary mechanisms to augment bilateral trade in this sphere.

CHAPTER 3

QUANTUM COMPUTING: BUILDING AN EFFECTIVE PARTNERSHIP

ARJUN KANG JOSEPH AND SHATAKRATU SAHU

Quantum computing can potentially have transformative effects across a number of sectors, including healthcare, finance, agriculture, cybersecurity, and logistics. Governments have also heavily invested in quantum because of its potential impact on national security and the defense sector.

India formally entered the global quantum computing race in 2020 with the announcement of the National Mission on Quantum Technologies and Applications with a budget outlay of approximately $968 million. Providing this ecosystem with the right stimulus, both domestically and through partnerships with its strategic partners, could propel it forward to compare with the likes of global leaders like China, the UK, and the United States.

The United States, though it is already a leader in this space, has also prioritized the development of its own quantum computing ecosystem in order to maintain its position and has backed these efforts with significant funding.

The intention behind the iCET is to facilitate outcome-oriented cooperation and forge closer linkages between the two countries' governments, academia, and industry. It could be a vehicle to promote the growth of the two countries' quantum computing ecosystems by leveraging their respective strengths and addressing common challenges like funding, education and the availability of talent, and hardware and manufacturing development. Some of the steps the two countries could take to create effective outcomes from this partnership are as follows.

FACILITATING PARTNERSHIPS, ENGAGEMENT, AND FUNDING

India and the United States could establish a focused partnership for quantum computing wherein stakeholders from academia, industry, and the governments are provided with a common platform or forum to collaborate among themselves and their respective counterparts in both countries. Beyond being a formal mechanism for these stakeholders to engage with each other, this platform or forum should focus on achieving the following three objectives.

Firstly, it needs to create a space for the stakeholders to engage in discussions on the pain points, challenges, and policy gaps that exist in quantum computing ecosystems in both countries. Second, it should serve as an avenue to keep stakeholders in the two countries' ecosystems apprised of the various research projects and applications of quantum computing being developed in both countries. Achieving these two objectives will enable the two ecosystems to draw on each other's experiences to optimize their own efforts as well as avoid duplicating their efforts and to facilitate collaboration between organizations working on similar applications. Lastly, the forum should serve as a space for academia, industry, and government from both countries to engage on creating a framework for the regulation of quantum technologies without negatively impacting innovation. Adopting a similar mechanism to the UK's Regulatory Horizons Council, which identifies the implications of emerging technologies on the economy and society and suggests regulatory reforms needed for the safe and rapid introduction of the technologies, would be a significant benefit to both ecosystems.

In order to further build a collaborative spirit among the stakeholders in both ecosystems, the two governments should create a joint fund that incentivizes and enables joint projects between academics, industry professionals, and governmental organizations in the two countries.

EDUCATION AND TALENT-BUILDING

Indian talent has historically been sought after in the technology sector, especially by the industry based in the United States. In the field of quantum computing, India has begun developing an educational system through its leading academic institutes with dedicated courses and centers. The United States, which has a demand for a quantum information science and technology workforce, could potentially benefit from the talent pool in India in order to build its workforce for quantum computing.

Industry in both countries, as the largest employers of the quantum computing workforce, should be asked to project their requirement of the talent and the skills this workforce should be equipped with. This projected requirement could then guide efforts by academia in both countries to collaborate on the creation of a co-syllabus that will enable the free movement of talent and knowledge between the two countries. This syllabus must have a focus on inculcating the interdisciplinary skills across hardware development and programming specialties needed for quantum computing. A first step toward the creation of such a syllabus should be conducting joint workshops between leading academic institutes focusing on quantum computing in India (such as IIT-Madras, IISC-Bengaluru, and IISER-Pune) and the United States (such as the MIT Center for Theoretical Physics, Chicago Quantum Exchange, and Harvard Quantum Initiative).

Another step that would contribute significantly to the development of this workforce would be the creation of partnerships that provide internship opportunities and training for students and young professionals. A similar model to the Indian government's recent partnerships to develop a semiconductor workforce could be adopted to train professionals. Indian students would benefit from visits to developed quantum labs in the United States and internships at leading U.S. companies, including IBM, ColdQuanta, Google's Quantum AI, and Microsoft's Azure Quantum, which all focus on the development of quantum hardware. Similarly, U.S. students could visit leading Indian quantum research centers and labs to learn how to develop quantum programs and applications that can function at scale in a diverse environment like India.

HARDWARE AND MANUFACTURING

Most governments place restrictions on the export of quantum hardware due to its strategic value and implications on national security. In such an environment, it is imperative for any nation with quantum aspirations to develop domestic manufacturing capabilities for quantum hardware.

The United States is a global leader in quantum computing capabilities: it has the highest number of country-issued quantum computing patents as well as a vibrant private sector for quantum computing, and U.S. companies lead the global quantum race in their own right. For instance, IBM's Eagle processor is presently the world's largest superconducting quantum computer of 127 qubits. In contrast, India is currently developing its quantum hardware capabilities and has an aim to develop a 50-qubit quantum computer by 2026. Through collaborative efforts and investment, India could significantly benefit from the United States' strength in manufacturing quantum hardware. The United States could help India to develop a basic level of manufacturing capacity and reduce its dependence on imports for essential components for quantum technologies.

In the interim, the U.S. relaxation of export restrictions on quantum hardware to India would be a welcome step. Another stopgap could be incentivizing tie-ups between Indian academic institutions and start-ups with U.S. companies to allow greater access to programs or initiatives like the IBM Quantum Network or Amazon Web Service's Braket service.

CONCLUSION

In the short term, a common platform and joint funding for projects will serve to increase engagement between the two ecosystems. In the medium term, the investment in a commonly trained workforce will address the need for talent to develop quantum hardware and software. In the long term, the development of hardware and manufacturing capabilities could result in both countries leading the global quantum race. These steps would make the iCET an effective vehicle to create a truly strategic partnership while unlocking the potential of quantum computing in both India and the United States.

CHAPTER 4

A U.S.-INDIA PARTNERSHIP ON SEMICONDUCTORS: TIME TO BET ON THE ICET?

KONARK BHANDARI

It has become trite to say that the world is witnessing a semiconductor shortage. In response to this pressing scarcity of semiconductors—which have applications not just in the commercial sphere but also strategic industries—various countries have come out with semiconductor policies of their own. But in a supply chain as complex as the one for semiconductors, it is unclear whether any one singular policy, no matter how remarkable, can position any one country ahead of others when it comes to attaining self-sufficiency.

In a global supply chain that has been built up over decades, these new policies will not lead to a *sudden* recalibration of supply chains, as relocating various parts of the process is a tedious and expensive proposition. In such a short- to medium-term scenario, the best nations can do is work together with like-minded partners to address any shortages that may emerge. However, it is important that such partnerships are leveraged for what they are worth. Rather than focusing on such partnerships as solely serving strategic needs to diversify supply chains and avoid chokepoints, they should also be viewed through a commercial prism. It is in this context that the recent U.S.-India iCET announcement of semiconductors as an area of cooperation is reassuring. This initiative will not simply look at government partnerships but will also aim at establishing industry linkages. While these are still early days, below are a few proposals as to how these linkages could be achieved.

RISC-V architecture collaboration. For the United States, given the massive funds being committed by other jurisdictions in chip fabrication, shoring up domestic fabrication will continue to involve substantial capital expenditure. An opportunity here could be to leapfrog the current state of semiconductor technologies by focusing on a novel architecture for chips, the fifth version of the reduced instruction set computing (RISC-V) architecture. The RISC-V architecture makes it much cheaper to design chips. It is based on open-source hardware, uses less memory, and has the potential to disrupt the semiconductor industry. India, through the Indian Institute of Technology Madras, is already working on an indigenous RISC-V processor called the Shakti microprocessor and had launched a Digital India RISC-V program for next generation microprocessors in April 2022. The main benefit of using RISC-V architecture is apparent—it is available free of cost. It is not licensed like Arm's microprocessor, which is used largely in mobile devices, nor sold like the x86 chips used in other computing devices. China has also realized the utility of these processors—of the eleven premier members in the Technical Steering Committee at RISC-V International, the nonprofit home of the open standard technology, eight are headquartered in China. India and the United States may therefore consider looking at this architecture as an avenue for closer cooperation and pursue joint development of a RISC-V microprocessor.

Exploring possibilities in joint skilling of talent. Engineering talent is very much available in India. However, a more holistic approach to what constitutes talent should be taken as per industry stakeholders' feedback. For instance, the real challenge lies in incubating talent in other areas, such as capital raising, product development/iteration, logistics, and branding. Therefore, hardware engineering is only one of the areas that needs encouragement. Similarly, in the United States, semiconductor industry professionals earn more than their counterparts in the software industry, but there are a limited number of hardware professionals due to the fact that the software industry has more labor market depth, which means that there are more jobs available in the software industry. India, through its Chips to Startup scheme, has already undertaken the task of skilling approximately 85,000 engineers at all stages of the semiconductor value chain. This would be implemented in partnership with one hundred academic institutions in India (largely Indian Institutes of Technology, Indian Institutes of Information Technology, and other R&D organizations). The United States has also kickstarted a similar initiative through the American Semiconductor Academy and SEMI that aims to connect more than 200 American universities with 1,500 semiconductor companies that have U.S. operations. Given that India has already tied up with the Agency for Science, Technology and Research (based in Singapore), the Industrial Technology Research Institute (based in Taiwan), and the Interuniversity Microelectronics Centre (based in Belgium) to train its professionals, another wide-ranging partnership should be explored with the American Semiconductor Academy and SEMI as a part of the Chips to Startup scheme that will bring American professionals under the fold of the training program as well, while also letting Indian engineers participate in the training programs of the American Semiconductor Academy and SEMI.

Considering all generations of technology nodes for chips. The Indian government unveiled a new semiconductor fabrication policy in December 2021. However, the stakeholder view appears to be that given the long gestation period of setting up a foundry in the leading-edge nodes segment, an equal focus ought to be placed on the mature nodes, which are relatively easy to manufacture and are also seeing a bigger shortage (especially in the 45–90 nanometer segment). Indeed, recently the Indian government revised its policy to reflect this line of thinking. Earlier, the Indian government provided more fiscal support to companies that undertook production of nodes below 28 nanometers, with progressively lesser fiscal support being provided to nodes from 28–45 nanometers and 45–65 nanometers. This differentiation has now been done away with. Four to five industries that use these mature nodes, such as point-of-sale (POS) terminals, security cameras, electric vehicles, and power electronic devices, among others, should be made into priority areas for the government. Foundries need to have high-capacity utilization rates (hovering around 95 percent) in order to be financially sustainable. Given the relatively less capital-intensive nature of such type of fabrications and the robust Indian sales figures for POS terminals, security cameras, electric vehicles, and power electronic devices, an opportunity exists for American chipmakers to set up and invest in such facilities.

There has been talk recently about the need to take a hard look at "friend-shoring," the term coined to describe a select group of nations that band together and limit "the trade of key inputs to trusted countries in order to reduce risks to the supply chains." The concerns voiced range from protectionist lobbies in other industries using this mechanism to restrict competition to oligopolies emerging in sectors that are subject to friend-shoring. However, these specific concerns are better addressed by rules that regulate lobbying and antitrust laws. In addition, suggestions that using supply chains will help create economic interdependencies among nations and, accordingly, lessen the prospect of war, are misplaced. For instance, China's thriving bilateral trade with both South Korea and Japan has not diminished the number of times bilateral trade has been held hostage to national security concerns, be it locating the Terminal High Altitude Area Defense (THAAD) missile defense system in South Korea or the privatization of the Senkaku Islands by Japan. The iCET, to its great credit, has realized that trade is not a zero-sum game that involves a community of nations trading with each other based only on their product specialization. Sacrificing supply chain resilience at the altar of efficiency is not going to find many takers in the immediate future where access to inputs like semiconductors becomes critical.

Like all industrial policies, which always contain an element of speculation, the semiconductor policies of both the United States and India are a gamble in making the supply chain more resilient and secure. Whether the iCET framework can become a platform upon which such domestic policies can be coordinated will be the real test of this partnership. But, to borrow a gambling phrase, the payoff down the line may be worth it.

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